2005 - 2010

Air Resources Laboratory
Strategic Plan

"The atmosphere as a part of the global environment"

Silver Spring, Maryland
Research Triangle Park, North Carolina
Oak Ridge, Tennessee
Las Vegas, Nevada
Idaho Falls, Idaho
Boulder, Colorado

Contents:

In the end, ARL is the assembly of its talents. One of ARL's main strategic goals must be to preserve and expand these talents, so as to meet the air quality challenges that will be confronting society in the future.

15 March 2004

1. PREFACE

The Air Resources Laboratory conducts research on processes that relate to air quality and climate, concentrating on the transport, dispersion, transformation, and removal of trace gases and aerosols, their climatic and ecological influences, and exchange between the atmosphere and biological and non-biological surfaces. The time frame of interest ranges from minutes and hours to that of the global climate. The Laboratory conducts research related to the NOAA mission, provides scientific and technical advice to elements of NOAA and transfers NOAA technology and science to other Government agencies whose missions relate to atmospheric science, environmental problems, emergency assistance, and climate change.

The Air Resources Laboratory is now well into its sixth decade. The evidence of its beginnings is still noticeable. To this day, ARL serves as the source of atmospheric transport and dispersion capabilities to the National Weather Service, to NOAA as a whole, and to a wide range of external users. The early focus was simply on the prediction of concentrations downwind of some specific emission source (e.g. a nuclear test), today the dispersion skills have broadened into many related areas of specialty. Out of the early awareness that radioactive fallout was a global issue grew the current activities related to climate and global change. From the need to consider the chemistry of pollutants arose the present emphasis on air quality and its prediction. From the recognition that mankind could modify the atmosphere on global scales came the ARL emphasis on climate and methods to detect changes in it. And from the awareness that pollutants are removed from the air through deposition processes came the ARL role in measuring and understanding wet and dry deposition and the growing activity in multi-media modeling of the whole environment. All of these activities are directly related to NOAA's core mission - the protection of people, the stewardship of the environment, and the prediction of changes in it.

Today, ARL operates with six research groups, each with its own research agenda but also each with a specific function within the ARL structure. The group at Oak Ridge, Tennessee, develops models to describe the processes of diffusion and deposition of pollutants. The group in Research Triangle Park, North Carolina, assembles the understanding of processes into coupled meteorology and air chemistry models, for application in air quality programs of the Environmental Protection Agency and other organizations (e.g. states). A further role of the Research Triangle Park group is to extend its air quality modeling to the provision of real-time forecasts, an activity that calls for close collaboration with the National Weather Service. The group at Idaho Falls, Idaho, specializes in conducting field studies to test the validity of dispersion models. At Silver Spring, Maryland, work concentrates on the development of dispersion models tailored for operational use, such as by the National Weather Service. At Las Vegas, Nevada, the dispersion capabilities are applied routinely in support of national security missions of the Department of Energy. In recognition of the fact that new models require increasingly more information on the surface energy budget, the group in Boulder, Colorado, operates research-grade measurement stations where the surface radiation balance is documented. Consequently, ARL is organized and managed to provide NOAA and other federal agencies an end-to-end model development, testing, and implementation capability. The success of the process is well illustrated by the fact that many models developed by ARL scientists are now fully operational, in DOE and the EPA as well as in the service Line Offices of NOAA.

The horrific events of 11 September, 2001, elevated ARL's dispersion expertise to a new level of importance. The dispersion work of ARL is now the nucleus of a rapidly developing program to institutionalize a next generation dispersion forecasting system, as a component of a more general air quality forecasting capability.

NOAA and ARL benefit from having an experienced, enthusiastic, and productive scientific core. It is to the staff of the laboratory that credit is due for the breakthroughs of the past, and it is upon the capabilities and foresight of this cadre of scientists that the future of the laboratory rests.

2. GOALS

ARL provides NOAA expertise to other federal and state agencies involved in the planning process related to man-made or natural disasters. In general, the question addressed is "What will happen if. . . and what should then be done?" The goal is to plan response activities to minimize danger and damage, and to help assess risk in time to avoid dangerous situations. In this regard, ARL works with many government agencies (including EPA, NRC, NASA, DOD, DOE, DOT, FBI) involved in the use or transport of hazardous materials. Meteorological models are required to address these critical questions and to propose actions.

Meteorological models have classically concentrated attention on those regions of the atmosphere in which weather systems generate and move. NOAA experience in using these models has demonstrated the need for a more comprehensive way of expressing boundary layer processes. This is especially important for predicting air quality; the atmospheric features that affect air quality tend to be strongly moderated by complexity of the surface. The mesoscale atmospheric models now in development will combine weather forecasting with a directly coupled accounting for the effects of local factors that influence the planetary boundary layer (PBL). Air quality models have demanded this kind of coupling for a considerable time. As a result, there are now well-developed descriptions of PBL processes in use in air quality models. The next generation of atmospheric models will make use of the extensive PBL knowledge now resident in the air quality community, and will be extensively data assimilative.

The scales involved are from local to continental, with some activities stretching to global. Of special relevance is the ARL specialization in the short-range dispersion of pollutants, especially heavy gases which tend to be greatly influenced by terrain and atmospheric stability. Several ARL groups (Research Triangle Park, Idaho Falls, Las Vegas) are actively involved in research on the dispersion and transport of heavy gases released near the surface.

> **The specific goal of ARL research is to improve and eventually to institutionalize both current assessment and future prediction of atmospheric dispersion, air quality, deposition, and related atmospheric environmental variables, with full allowance for the roles of climate change and variability.**

3. ORGANIZATION

ARL is organized as an array of specialized Divisions that work in close collaboration, regardless of their geographic separation.

Headquarters Division, Silver Spring, Maryland:
Director – Bruce B. Hicks; Deputy Director - Richard S. Artz

The Headquarters Division concentrates on developing products to augment the operational product suites of the NOAA service-oriented line offices. In this context, research activities include the development of improved dispersion models for emergency response, advanced methods for detecting and quantifying climate variability and climate change, and studies of atmospheric wet deposition.

Atmospheric Sciences Modeling Division, Research Triangle Park, North Carolina:
Director – S. T. Rao; Deputy Director – William T. Petersen

This group, the largest within the ARL system, focuses on the development of numerical models for predicting air quality and atmospheric deposition. The emphasis is on completeness, as is required for scenario development and policy applications., The most recent product of this intensive model development effort has been the MODELS-3 Community Multiscale Air Quality Model, now widely used as a benchmark for developing air quality regulations in the USA and in many other countries. This division serves as the center of interaction between NOAA and the Environmental Protection Agency.

Atmospheric Turbulence and Diffusion Division, Oak Ridge, Tennessee:
Director – Rayford P. Hosker, Jr.; Deputy Director – Tilden P. Meyers

Originally prominent as the Atmospheric Turbulence and Diffusion Laboratory (ATDL), this Division has extended its formative research focus to include atmospheric dry deposition and air-surface exchange in general. The work includes consideration of atmospheric behavior in complex terrain. Unique expertise in instrumentation and the development of new measurement techniques has led to several new and exciting roles, such as in the instrumentation of the Climate Reference Network of NOAA.

Field Research Division, Idaho Falls, Idaho:
Director – Kirk L. Clawson

This group specializes in field studies designed to test the predictions of atmospheric dispersion models, through the use of inert atmospheric tracers. In recent years, a new program has grown, focusing on the development of specialized instrumentation for use by small aircraft in geosciences research. In support of this work, the group has developed an advanced instrumentation development capability whose products now permit use of light aircraft in studies of air-sea interaction, for example.

Special Operations and Research Division, Las Vegas, Nevada:
Director – Darryl Randerson; Deputy Director – Douglas Soulè

This Division was originally set up to provide meteorological (primarily dispersion) expertise in support of test programs conducted at the Nevada Test Site (NTS). The group now serves as the ARL unit actively transferring dispersion products developed within ARL (and elsewhere) to the emergency response community and to direct support of national defense projects conducted on the NTS. A comprehensive meso-scale meteorological network is operated, which includes monitoring of lightning. A research program to focus on the special air quality concerns of arid environments is now in place, as a joint venture with the Cooperative Institute for Atmospheric Studies and Terrestrial Applications (CIASTA).

Surface Radiation Research Branch, Boulder, Colorado:
Director - Joseph Michalsky

Much of ARL's developmental activities focus on the behavior of the lower atmosphere, where turbulence is a controlling consideration. The driving force is solar heating of the surface. This Branch concentrates on providing radiation data for model developers and for assimilation into their products. The same observations are of direct relevance in the context of climate change studies, and of radiation exposure regimes. SRRB also operates the national Central UV Calibration Facility.

4. ACCOMPLISHMENTS

The origins of ARL lie with forecasting the spread of radioactive fallout. As time has progressed, the focus of the work has changed. However, the purpose has remained constant – to provide NOAA and the agencies with which NOAA works with the atmospheric dispersion and air quality modeling tools they need to satisfy the requirements of their own missions. The following is a listing of major accomplishments of ARL scientists, many leading to operational products that remain in use. Italicized items are now operational.

In the 1950s and 1960s, ARL scientists –

- *developed plume rise and Gaussian plume dispersion models*
- *developed puff dispersion models*
- studied stratospheric dispersion and developed relevant dispersion models
- *started long-term global monitoring*
- developed relationships with the Public Health Service and the Atomic Energy Commission, which evolved into long-term associations with EPA & DOE
- *helped develop electron capture ion chromatography*
- served as meteorological advisers to US nuclear weapons programs

In the 1970s and 1980s, ARL scientists –

- conducted major tracer studies, focusing on complex terrain
- *developed simple urban dispersion models*
- *constructed the US global monitoring network*
- *initiated deposition monitoring* for the continental United States

- *developed trajectory models*
- *developed data transfer systems for the NWS*
- *developed regulatory air quality models*
- constructed the major US physical modeling laboratory
- led research under NAPAP
- initiated dry deposition research and the *dry deposition monitoring network*

In the 1990s, ARL scientists –

- Conducted major tracer studies in coastal areas
- *Developed the Community Multiscale Air Quality modeling system (CMAQ)*
- *Developed the models used for dry deposition quantification*
- Led the meteorology component of the White House Interagency Nuclear Safety Review Program
- Integrated agency UV measurement programs into a coherent national program through the Central UV Calibration Facility.
- Accepted responsibility for national surface radiation programs from the NWS, and developed the ISIS and SURFRAD programs
- *Developed the open path CO_2 and H_2O sensor (IR)*
- Initiated routine CO_2 sequestration measurements, leading to FLUXNET, EUROCARB, and Ameriflux
- Conducted trials of air quality forecasting for New England, Texas, and the southeast
- Completed the NOAA Nuclear Emergency Response Plan
- Developed and tested forest fire smoke forecasting systems
- *With NCEP, assembled the US Regional Specialized Meteorology Center for dispersion*
- Led the civilian part of the US response to the Kuwait oil fire emergency following the Gulf War

In the 2000s,

- *Institutionalized HYSPLIT at NCEP, and in other countries (China, etc.)*
- *Restructured the READY system to user-registration configuration*
- Conducted urban tracer studies – Salt Lake City and Oklahoma City
- Led the multi-agency BRAVO study (Big Bend, Texas)
- *Operationalized the Sky Arrow airborne flux system*
- *Designed, calibrated and installed stations of the US Climate Reference Network*
- Developed new NOx/NOy detector systems for Twin Otter deployment
- Completed initial development of a multi-media modeling system (MIMS)
- Conducted dispersion studies in New York following the WTC attack
- Led OFCM reviews of dispersion models
- Developed systems for assimilating satellite observations into dispersion models
- Promoted the Washington DCNet, an urban testbed for developing dispersion systems
- With other agencies, developed plans for an Urban Atmospheric Observatory in New York City
- Developed the relaxed eddy accumulation system for measuring air-surface exchange
- Studied and explained the Arctic "mercury sunrise" phenomenon
- Studied the Florida everglades mercury problem
- Initiated new studies of the rate of CO_2 uptake over both land and water
- Led the BRACE program – a study of pollution affecting the Tampa Bay watershed

5. SPONSORS and CLIENTS

The customers for ARL research are the Line Offices of NOAA and the agencies (federal and state) that collaborate with NOAA on programs of mutual interest. ARL relies upon close relationships with other NOAA organizations, especially the NOAA Research Laboratories, Joint Institutes, and Sea Grant Colleges. Equally important are the partnerships with other agencies -- in practice and by intent, ARL is the major point of interaction between NOAA atmospheric research and the related informational and scientific requirements of several other Federal agencies. In general, NOAA is viewed by these organizations as the provider of high-quality and independent advice regarding matters of atmospheric transport, dispersion, air quality, and deposition, and ARL is perceived to be the agent providing access to this advice.

ARL works closely with the Line Offices of NOAA in the development and refinement of operational products. ARL has a commendable history of developing products in close collaboration with the personnel of the Line Offices in which these products will become operational. In essence, ARL advocates development based on early collaboration with eventual customers, rather than on independent development followed by a program of technology transfer.

The activities of ARL contribute to the goals of the NOAA Strategic Plan, but also address a higher level of consideration – NOAA's role as a source of atmospheric and aquatic environmental guidance to other elements of society and especially to other federal and state agencies. Much of the contribution made by ARL can be viewed as providing independent atmospheric expertise to assist other agencies in fulfilling their own Federal mandates related to air quality and atmospheric dispersion. This provision of scientific information and advice to other organizations is an important component of NOAA's service function. Financial support for work intended to permit another agency to perform its own function, in its own jurisdictions, with improved credibility and defensibility, is normally provided by the other agency concerned through long-term arrangements solidified in Memoranda of Understanding and Interagency Agreements. At this time, the major agencies involved are the Environmental Protection Agency (EPA), the Department of Energy (DOE), and the Department of Defense (DOD). ARL is supported by NOAA, EPA, DOE, and DOD, each contributing about the same amounts each year. Support from DOE and EPA is focused on specific ARL Divisions. Support from DOD is distributed more widely across ARL.

The Environmental Protection Agency provides considerable support to the ARL team at Research Triangle Park (RTP), initially set up specifically to provide meteorological expertise and guidance to the Public Health Service (the forerunner of the EPA), related to atmospheric dispersion and air quality modeling. In recent years, the RTP group has become a central player in the program to institutionalize air quality forecasting in NOAA, a joint NOAA/EPA activity.

The Department of Energy provides about 10% of the funding for the ARL team at Oak Ridge, originally set up to provide a collaborative NOAA/DOE capability to address questions on dispersion, deposition and air quality of relevance to the DOE Oak Ridge Field Office. DOE also provides about 25% of the funding at Idaho Falls for maintenance and improvement of emergency assistance services to the Idaho National Engineering and Environmental Laboratory. DOE provides almost all of the funding of the ARL Special Operations and Research Division in Las Vegas, to support missions of the DOE Nevada Site Office.

At the time of this writing, ARL operates with about half of its funding from sources outside of NOAA. Only about 15% of ARL funding is short-term "reimbursable."

6. NOAA Mission Goal 1: PROTECT, RESTORE, AND MANAGE THE USE OF COASTAL AND OCEAN RESOURCES THROUGH ECOSYSTEM-BASED MANAGEMENT

The ARL objectives are –

6.1 Air-Surface Exchange. Air-surface exchange of atmospheric constituents is a long-standing specialty of ARL. Elements of this specialty contribute to the accomplishment of all of the NOAA Mission Goals addressed here. In essence, the transfer of heat, moisture and momentum is a critical process affecting weather prediction, the exchange of CO_2 corresponds to the measurement of carbon sequestration, the emission of chemicals from the surface is a key factor in air quality prediction, and in the present context the deposition of airborne pollutants constitutes an often-ignored but frequently substantial pollutant loading of sensitive ecosystems.

6.2 Multimedia Modeling. Many of the most difficult challenges facing NOAA span environmental media. Effectively addressing these issues requires an improved understanding of cross-media processes. ARL plays an active role in the development of process-based numerical models and model components to address, through linkage or full coupling, inherently multimedia aspects of ecological stress. Specific research tasks address atmospheric deposition for nitrogen/nutrient cycling and acid deposition and the cross-media interaction of mercury and other toxic pollutants in the environment. Specific multimedia issues are of widespread concern. ARL research is aimed at improving our understanding and characterization of critical cross-media processes that challenge decision makers at state, regional and national scales now and in the future. Current research activities focus on the Canaan Valley in West Virginia, where ARL's measurement programs extend from incoming solar radiation to water quality. Other focal areas include the Chesapeake Bay, the Albemarle/Pamlico Sound, and Lake Champlain.

6.3 ARL Plans – near, intermediate, and long term

Near Term (0-5 years)

- Complete the mid-Atlantic highland (Canaan Valley) monitoring site.
- Assess nitrogen deposition rates to the upper watershed of the Chesapeake Bay.
- Assess nitrogen deposition rates to the Delmarva Peninsula.
- Complete (in collaboration with the State of Florida and other partners) the nitrogen cycling study of Tampa Bay and its environs (the Bay Regional Atmospheric Chemistry Experiment).
- Work with other agencies to study air-sea interaction in both light and high winds.
- Develop instrumentation to measure air-sea exchange rates in extreme conditions.
- Expand chemical transport models (e.g., CMAQ) to better address a wider variety of pollutants including mercury and other metals.
- Develop and improve meteorological process models critical to the description of the inter-media exchange of pollutants.
- Develop and/or improve surface exchange models describing the transport, deposition and fate of pollutants, especially nutrients.
- Develop integrated, multimedia pilot programs to help develop integrated multimedia atmosphere-ecosystem models.
- In conjunction wih other groups, set up and instrument test beds for directed model development.
- Initiate Investigation of statistical ecosystem models.

Intermediate Term (5-10 years)

- As identified in NOAA plans, work with Sea Grant and NOS to generate complete pollutant balances for demonstration watershed(s).
- In collaboration with other agencies refine models of areal deposition and apply to selected estuaries-- e.g. the Neuse River and the Chesapeake Bay.
- Couple deterministic atmospheric models with statistical (and other) ecosystem models, and initiate diagnostic evaluations.
- Expand fine-scale modeling research beyond land-surface processes, including sub-grid scale methods to link multimedia concentrations to individual, species and population exposure.
- Expand scientist and cooperative research exchanges to support pilot atmosphere-ecosystem model development.

Long Term (10-15 years)

- Demonstrate multimedia research capability through completion of relevant case studies.
- Promote access of decision makers to the results of these studies.
- Implement a model evaluation process based on the atmosphere-ecosystem case studies.
- Evaluate multimedia statistical and other methods for practical implementation of the multimedia understanding.

7. NOAA Mission Goal 2. UNDERSTAND CLIMATE VARIABILITY AND CHANGE TO ENHANCE SOCIETY'S ABILITY TO PLAN AND RESPOND

In its early days, the Air Resources Laboratory initiated studies of the changes in air chemistry due to emissions from industry and other societal sources. The first work concentrated on airborne radioactivity. In the 1960s, studies of trends in CO_2 concentration were started. These CO_2 monitoring programs have grown into the familiar array of global atmospheric monitoring activities. Since the formation of the Climate Monitoring and Diagnostic Laboratory, relatively few of the early monitoring activities remain within ARL - those that do are largely confined to the continental USA, where ARL maintains the nation's solar radiation and air-surface exchange networks.

However, several of the programs to analyze and interpret the data obtained and to provide related guidance to policy makers remain.

The ARL objectives are --

7.1 Climate Trends and Variability. ARL climate analysis work is focused on the development of methodologies to extract weak climate signals from noisy atmospheric data. The observational records of relevance include the radiosonde data sets of the world's hydrometeorological centers, surface radiation data, cloud cover information, etc. A parallel program seeks information on climate trends by research-quality direct measurement. The national surface radiation monitoring program (SURFRAD) is run by ARL, with a coupled program to quality assure all of the nation's UV measurement programs. ARL developed the methodologies now globally used to measure the rate of CO2 exchange between the air and the surface. These methods are deployed at a subset of SURFRAD sites, and are additionally stationed at other locations of the US AmeriFlux network. The same sites routinely report the rates of exchange of heat and water vapor between the surface and the air, yielding data of major importance to regional hydrologists, climate modelers, and weather forecasters. Cloud cover is measured automatically, using new systems developed by ARL. SURFRAD sites are among the first to be instrumented as part of the new Climate Reference Network, being set up by ARL for NESDIS.

7.2 Global Climate Change and Air Quality. Global climate change may make it more difficult for the United States to achieve its air quality standards or goals in the future, at a regional and local level. Conversely, the air pollution emanating from the U.S., including methane, CO_2, particles, and other constituents, may influence future climate trends. Climate change impacts are only evident on long time scales (decades to centuries) and thus are difficult to detect.

For many years ARL science has been directed towards resolving questions related to the changes in the atmospheric chemical environment expected to be associated with climate change, either as causative influences or as consequences. Expanding industrialization in Asia is a major concern. Hence, a first goal of this research area is the assessment of intercontinental transport, primarily of Asian dust and pollution. A second aspect of this research is the assessment of global climate change on regional/urban air quality. A third research area is the assessment of regional air quality on global climate change. The ARL research contributes to the 2007 and 2010 assessments to which the US Global Climate Research Program (USGCRP) is committed. In this context, special attention is being given to the accumulation and transformation of mercury in high latitude ecosystems.

7.3 ARL Plans – Near, Intermediate, and Long Term

Near Term (0-5 years)

- Complete Climate Reference Network installations at all SURFRAD sites.
- Institutionalize formal QA/QC programs for the CRN.
- Complete examination of new sensors for CRN deployment.
- Formalize aerosol optical depth algorithm for multi filter rotating shadow band radiometers.
- Develop techniques for determining trends in key atmospheric variables, and understand linkages with air quality, surface energy balance, etc.
- Formalize association and alignment with GCOS/GAW.
- Institutionalize association with NCEP, for applications requiring routine SURFRAD data.
- Develop data interpretation methods (including satellite data) to assess present-day magnitude, timing, and location of trans-Pacific transport
- Integrate ozonesonde and remote sensing data to improve the vertical boundary condition in air quality models.

Intermediate Term (5-10 years)

- Improve methods for detecting slow trends in poorly observed atmospheric variables.
- Assess changes in air quality and atmospheric deposition likely to accompany climate change.
- Understand the behavior of ecologically important atmospheric chemicals in sensitive regions, e.g. mercury in the Arctic.
- Study CO_2 sequestration and explain the causes of year-to-year variability.

- Quality assure AMERIFLUX and FLUXNET data obtained by NOAA/ARL.
- Examine methodologies for spatial interpolation using light aircraft flux systems.
- Examine linkages between CO_2 sequestration and drought (and related climatic variables).
- Working with other CO_2 sequestration groups, assemble annual summaries of national and continental CO_2 sequestration.
- Develop and assess air quality emission scenarios for 2050 and possibly 2100
- Assessment of changes in relevant weather conditions - changes in extremes and the frequency of occurrence of weather conditions leading to adverse air quality
- Test sensitivity of air quality predictions to meteorological conditions under climate change scenarios
- Express model results in probabilistic form, reflecting uncertainties.

Long Term (10-15 years)

- Assess the impact of US/North American emissions on greenhouse trace gases and particle concentrations (including O_3, CH_4, CO, black carbon, aerosols, N_2O, CFCs)
- Project future emission scenarios (50 to100 years)
- Integrate global and regional models to quantify the consequences of relationships between air pollution events and meteorology, and potentially longer-term climate.
- Generate long-term base support for SURFRAD and related integrated monitoring programs.

8. NOAA Mission Goal 3. SERVE SOCIETY'S NEEDS FOR WEATHER AND WATER INFORMATION

The ARL objectives are –

8.1 Air Quality Assessment and Dispersion Research. Computer modeling of atmospheric processes related to air pollutants is a primary mission of ARL. Following the "one atmosphere" concept, the main tools for computer simulation of a multitude of air quality issues are currently the Community Model for Air Quality (CMAQ) system and the various forms of the HYSPLIT system. CMAQ is fully Eulerian. HYSPLIT is a combination of Lagrangian and Eulerian approaches. The selection of an optimal approach depends on the nature of the application. Both systems have been under development for more than a decade, and continue to be refined.

The use of hybrid modeling systems (e.g. HYSPLIT) to address the air quality consequences of specific injections of pollutants into the atmosphere will continue. In the past, the systems have been widely used in studies of long-range transport of pollutants. At the time of this writing, application to volcanic ash plumes and the international transport of radioactivity is operational within the National Weather Service, while development of the capabilities continues. Experimental application to the plumes from forest fires is starting, in collaboration wth the US Forest Service.

8.2 Air Quality Forecasting. The goal of this program is to operationalize real-time forecasting of airborne material. This task will deploy a cadre of scientists with expertise in air quality modeling (atmospheric chemistry, emissions inventories, boundary layer meteorology, numerical optimization, and model evaluation) and meteorological forecasting (operational model application and model output statistics). While ARL possesses much of this expertise, interaction with other groups (in other agencies as well as in NOAA) will help in leveraging available resources.

While the real-time national forecast model is initially addressing ozone only, it is planned to add fine particulate, predictions of visibility, deposition, toxics (for acute exposures), and events (such as wildfires and hazardous material releases). The air quality forecasting system will be designed to simulate regional-scale (20-50 km resolution) as well as urban-scale (2-20 km resolution) pollution patterns.

The national real-time air quality forecast model will equip state and local air quality agencies with a tool for making accurate, multi-day predictions of air quality. These forecasts can then be used by the public to reduce their exposure to harmful levels of ozone and PM during elevated pollutant episodes. The real-time modeling results can also be used to help decision-makers in issuing air pollution advisories, for regulating controlled-burns, for taking voluntary control measures, and for helping the public to visualize air quality patterns. An important fringe benefit of the real-time air quality modeling effort is that it will help the development of regulatory air quality models, by providing a continuous database that can be used to rapidly identify and correct scientific weaknesses in the emissions and meteorological data as well as in the model physics and chemistry. Ultimately, the scientific improvements resulting from real-time air quality model application will serve to improve the current suite of air quality models that are being used for making emissions management decisions at the state/regional level.

8.3 Model Evaluation. The ability of modeling systems to replicate the meteorological and chemical processes responsible for the emission, transport and fate of various species and to predict the consequences of changes in emissions can only be determined through rigorous model evaluation. Such evaluation can be broken down into three major components: *performance evaluation, diagnostic evaluation,* and *uncertainty evaluation.*

Performance evaluations involve comparison with observations and other modeling systems. Diagnostic evaluation employs sophisticated chemical and physical combinations of *in situ* variables and depends on smaller spatial/temporal scale data sets (e.g., intensive field studies). Characterization of uncertainties involves the creation and analysis of output distributions that reflect the uncertainties associated with the various model components (i.e., uncertainties in input data, algorithms, parameterizations). All three components of model evaluation need further attention.

8.4 Urban Weather, Air Quality and Dispersion. For many decades, ARL scientists have been developing dispersion models for application where people work and live, primarily urban areas and cities. Two recent events have elevated the importance of such urban meteorology studies. First, the terrorist attack of September 11, 2001, alerted the population to the fact that current capabilities to forecast dispersion in urban surroundings is exceedingly limited. Second, the mandate relating to the provision of air quality forecasts imposes the need to forecast human exposure; it is well known that urban areas experience different meteorology than do rural areas.

In the past, research has been dominated by short, intensive studies to explore controlling processes. These must continue. However, the goal of this program is necessarily related to the exposure regimes of people, at all times. Hence, the concept of urban test beds arises. Many urban areas are either in violation of ozone and particulate standards, or are at risk of exceeding them in the near future. It is the ARL intent to promote the concept of urban test beds and to participate in such studies as much as is possible. The work will be directly coupled with the activities identified under the general heading of “Homeland Security,” below. The cities currently identified by ARL programs for initial consideration are dominated by areas in the east, but also include a key test bed in the west – Las Vegas.

- The National Capital area, where the ARL DCNet program is already under way
- New York City, and the Urban Atmospheric Observatory that is now being planned
- Houston, the focus of the multi-agency air quality study planned for 2006
- Philadelphia, where EPA is already targeting modeling and other studies
- Las Vegas, the fastest-growing urban area in the nation

It is proposed that each of these test beds be instrumented with remote-probing instrumentation to address air quality and urban meteorology issues for all seasons in a manner that joins directly with the air quality forecasting goals of NOAA and EPA and the public protection goals of the Department of Homeland Security. As part of this program, ARL scientists will build upon existing skills related to numerical modeling (specifically including computational fluid dynamics), physical modeling, and field measurement .

8.5 ARL Plans – Near, Intermediate, and Long Term

Short term (0 - 5 years)

- Evaluate fully Eulerian and Hybrid forecasting systems.
- Engage the private AQ forecasting community in joint development activities.
- Develop data assimilation methods for air quality application.
- Improve the Biogenic Emissions Inventory System (BEIS), with an increased emphasis on oxygenated compounds and particulate matter (PM) precursors.
- Improve analytical and visualization techniques to help improve emission inventories.

- As determined by the OAR/NCEP collaboration, continue the transfer of optimal models to fully operational status.
- Develop a new tracer sampling and analysis system.
- Complete the purchase of a new air-surface exchange aircraft system, and commence related research.
- Implement the first urban testbeds, starting with Washington, New York, Houston, Las Vegas, and Philadelphia. Complete tracer studies in each of these locations, as funding permits.
- Institutionalize a national dispersion forecasting system for local application.
- Working with DTRA and other agencies, plan and conduct field studies of dispersion processes in field situations.
- Promote and conduct physical laboratory studies of dispersion processes in order to extend the results of field investigations.
- Complete systems integration with NESDIS for access to dual use data.
- Couple improved forest fire source term algorithms with plume models.
- Extend forest fire forecast capability to chemical composition.
- Deliver a refined HYSPLIT forest fire smoke forecast system to USFS and other agencies
- Improve and verify long range transport and diffusion models as used in studies of trans-boundary exchange of pollutants and intercontinental transport.
- Refine source-receptor understanding for a range of atmospheric pollutants.
- Continue the ETOS series of studies.
- Formalize interagency relations related to ETOS, and institutionalize studies of the southeast within the NOAA air quality program.
- Extend atmospheric mercury studies to other locations to reveal air chemical processes and quantify atmospheric deposition rates.
- Refine methodologies for quantifying and measuring atmospheric deposition, wet and dry.
- Develop techniques for interpolating among measurement locations
- Operationalize the results of NOAA research on nighttime meteorology
- Continue integrated studies of variations of land use and topography on air-surface exchange, using numerical models and aircraft
- Improve modeling of secondary organic aerosol formation.
- Create an air quality "Data Repository" of observations to be used in evaluations.
- Develop advanced statistical techniques for model evaluation.

Intermediate Term (5-10 years)

- Develop operational systems for acquiring real-time air quality data and for employing them for data assimilation and model evaluation. Similar for satellite data.
- Use verification statistics during model operation to improve air quality modeling.
- Improve emission inventories through the use of inverse modeling and near-real-time data.
- Consider meteorology/emissions feedbacks (e.g. fugitive dust and wildfires).
- Perform research on fast chemical solvers and aerosol chemistry enhancements and achieve computational efficiency for CMAQ.
- Incorporate fine-scale features associated with urban areas into the national real-time forecast model.
- Develop systems to describe the feed back between chemical, particularly aerosols, and radiation schemes in air quality models.
- Improve systems to describe complex flow regimes such as land-sea breeze and complex terrain
- Develop methodologies for improving descriptions of nighttime meteorology on air quality models, with emphasis on nocturnal jets.

Long Term (10-15 years)

- Increase model speed and perform pattern recognition research.
- Test model ensemble predictions and calculate uncertainty of predictions.
- Incorporate boundary conditions (chemical and meteorological) from global models into assessment codes.
- Develop a bi-directional chemical flux module within chemical-transport models.

9. CROSS-CUTTING PRIORITIES

The ARL objectives are –

9.1 Homeland Security. The terrorist attacks of September 11, 2001, and the threat of further harm to U.S. interests have had a strong influence on the programs of the Air Resources Laboratory. ARL's historic role as a leading provider of dispersion forecasts has positioned the laboratory as a key provider of NOAA products to the corresponding emergency response communities, now coordinated under the auspices of the Department of Homeland Security (DHS). DHS looks to NOAA for the provision of meteorological guidance required to protect society from the consequences of terrorist attacks and to plan for anticipated attacks. ARL is the provider of dispersion expertise within NOAA.

The National Security programs of ARL involve close association with classified activities in other agencies. A considerable number of ARL scientists carry security clearances at levels unusual elsewhere within NOAA.

9.2 Urban Test Beds. The history of weather forecasting has been dominated by the needs of aviation and the limitations imposed by computer power. The scales of forecasts have been such that whole cities have been addressed as a single entity. Today, there is rapidly emerging need for more refinement, for forecasting for individuals and for specific locales. At the same time, computer power has expanded so that this vision is now achievable. What is needed is the necessary understanding of the processes that control urban weather, as modifications of the meteorological regimes in which they reside.

Concerns about air quality add more weight to the argument in favor of a focus on urban meteorology. Now that provision of air quality forecasts is an expected deliverable of NOAA, it is increasingly clear that prediction of dose is the main desired product. From the perspective of the individual, it is not the concentration of some pollutant at a point in space and time that is critical, but rather it is the exposure and dose to which each individual will be subjected. Concerns about the provision of accurate forecasts of dispersion add further to the need. It is well known that wind directions and stability regimes are greatly affected by the presence of surface structures, especially the buildings of urban areas. In the event of a release into the air of some hazardous material, it is first necessary to move people out of harm's way. Dispersion forecasts are then needed, and these must be accurate or else we risk moving people into harm instead of away from it. After the emergency is over, cleanup of hazardous materials and detailed studies of the doses delivered to people in different locations will be needed. The necessary skills remain to be established.

These factors combine to generate a new but rapidly evolving awareness of the need to address urban meteorology. Classical studies have been short-term "intensives," to reveal the details of contributing processes and to assess the role of variations that cannot yet be addressed using deterministic models. These intensive studies must continue. But we are now aware that the answers generated in summer at one particular setting are possibly not useful to address behavior at another location, or in another season. For this reason, and in complete awareness that a few particular urban areas are likely targets of future terrorist attention, ARL is setting up number of urban meteorology and air quality test beds, some as NOAA activities and others as multi-agency cooperative ventures.

ARL's historic involvement has been extensive. Early field programs such as in St. Louis (led by ARL in 1969/70) and the Washington, DC, area (1984) have led to several recent urban dispersion field programs (Salt Lake City, Oklahoma City) that rely on extensive use of ARL's tracer capabilities. The physical modeling system at Research Triangle Park (collaborative with EPA) was used extensively to explore likely exposures after the events of 9/11. While it is difficult to obtain a sufficient number of real-world measurements to truly characterize how pollutants vary through urban street canyons, computer simulations complemented by measurements using scaled physical models allow for estimation of the variation. The capabilities residing in ARL form the core of studies of urban meteorology that is now developing under this program. The focal areas for ARL attention are as listed above (see section 8.2).

9.3 Global Observing System

ARL advocates the close coupling of measurements and modeling. In line with the dispersion and air-surface exchange specialties of ARL scientists, ARL has concentrated on integrating its research measurement programs with modeling, and on collocating measurement stations as much as is possible considering the siting requirements of specific measurement approaches. ARL's research monitoring activity starts with measurements of the surface radiation budget. The Integrated Surface Irradiation Study (ISIS) is the continuation of the long-running NOAA solar radiation monitoring program, measuring incoming visible and ultraviolet radiation. The SURFace RADiation program (SURFRAD) adds outgoing and infrared components. Extension to the total surface energy budget is accomplished by adding routine eddy correlation systems at a number of locations. This Energy Balance Network also provides direct measurements of carbon dioxide sequestration rates. The Atmospheric Integrated Research Monitoring Network (AIRMoN) extends these studies to the air-surface exchange of trace gases and particles, with a wet deposition component and a dry. AIRMoN is a research technique development system, serving the needs of the national routine deposition networks – the National Atmospheric Deposition Program (NADP) and the EPA Clean Air Status and Trends Network (CASTNet). These various ARL measurement programs are brought together under the ARL Atmospheric Coordinated Observations and Research Network (ACORN).

A central theme of ARL's coupled measurement and monitoring program is that we need to monitor the factors that cause changes in the global environment as well as indicators of such changes. Classical monitoring programs are designed to reveal changes as they occur. ARL's integrated monitoring approach is focused on the factors that control such changes, with coupled modeling so as to help improve their prediction.

9.4 ARL Plans – Near, Intermediate, and Long Term

Near Term (0 - 5 years)

- Complete DCNet/UrbaNet instrumentation of areas selected as urban test beds
- Conduct tracer studies at each test bed, addressing all seasons
- Assess the utility of using fugitive sources "of opportunity" in continuing tracer studies
- Complete development of the stand-alone dispersion forecast system using derived data
- Assess the utility of data from other urban networks
- Complete wind tunnel modeling of selected urban test bed areas
- Conduct computational Fluid Dynamics studies of test beds, and condense the results into forms useable in dispersion forecasting.

Intermediate Term (5 - 10 years)

- Operationalize the enhanced urban area forecasting system within the NWS infrastructure
- Work with the WMO "GURME" program to extend the program to other major cities, globally
- Apply the testbed results to other areas, and evaluate future program needs

10. A VIEW OF THE FUTURE - ANTICIPATED TRANSITIONS

Air quality forecasting has been a documented goal of ARL research for ten years, and is now close to fruition. Two ARL modeling systems are being tested, one a fully Eulerian system and the other a hybrid Lagrangian system. The former will be the operational air quality forecasting tool of NOAA. The latter are better suited for specialized applications such as forest fire plume forecasting. It is the ARL plan to continue development in both areas.

ARL will continue to be the mainstay of air-surface research and measurement within NOAA. To this end, the ISIS and SURFRAD arrays will be consolidated into a single research-grade monitoring system, providing data as needed by the evolving generation of mesoscale meteorological and air quality models as well as quality- assured information suitable for extracting climate trend information. As many as possible of these sites will be a part of the new Climate Reference Network (sponsored by NESDIS), which also operates as a research-grade monitoring program. In addition, those sites that have suitable surroundings will be instrumented to monitor exchange rates of convective heat, water vapor, and CO_2, thus providing additional benchmark reference data for the new numerical models. All of these activities constitute reference points for programs to interpret satellite data.

The numerical models now in development are susceptible to error due to their assumption that point values as monitored by the ARL programs are representative of larger regions. Field studies already conducted by ARL show that this is not so, and that the difference might be large for trace chemicals like ozone and carbon dioxide although comparatively small for heat exchange. It is an ARL goal to develop the understanding necessary to interpolate among surface observation stations, and to extrapolate beyond them. To this end, a light aircraft program is central to ARL's science of the future.

Forecasting atmospheric dispersion will remain a mainstay of ARL's science, with application in a number of new areas of concern (e.g. downwind of forest fires, cities and suburbia). On all scales, the reliance on actual observations will increase – regionally using satellite data and locally using meteorological data from dedicated networks as well as observations "of opportunity."

11. ARL MANAGEMENT GOALS, STRATEGIES, and ACTIONS, 2005 – 2010

1. Management and Budget

- Working with OAR, develop a system for streamlining continuing operations with other agencies under the new NOAA accounting and budget system (CAMS).
- Continue the ARL Monthly Activities Reports.
- Actively engage in information transfer regarding ARL accomplishments, through the Hot Items mechanism and by individual promotion as warranted.
- Ensure long-term support for the Quality Control Center of the Global Atmosphere Watch.
- Obtain base funding to support the ARL component of NOAA's emergency response capability.
- Develop an integrated ARL research light aircraft program.
- Link the ARL climate services activities with NESDIS and NCEP.
- Integrate the various ARL IT systems, with a formal IT program in place.
- Improve ARL IT security, through formalized planning, procedures and testing.
- Develop an accounting system to show and explain the ARL overhead structure.
- Continue to emphasize safety, and provide detailed training to address specific ARL needs.
- Continue to improve the Continuity of Operations Plan (COOP).

2. Staffing and Personnel

- Actively promote the NOAA Survey Feedback system, identifying existing or potential problems and implementing appropriate actions.
- Continue the ARL awards system, for published papers and accomplishments.
- Encourage collaborations with universities, through sabbaticals and other assignments.

3. Outreach

- Build associations with local schools at every ARL location
- Refine and expand the Idaho Falls community outreach program.
- Participate in Science Fairs and other similar activities, providing awards for projects relating to NOAA interests.

4. EEO and Minorities

- Continue laboratory association with Minority Serving Institutions graduate programs
- Expand existing collaboration with minority serving institutions
- Integrate ARL Delmarva Peninsula nutrient studies with other-agency studies.
- Continue collaborative studies with Florida~A & M University.
- Continue participation in the PHASE program, in collaboration with Colorado University.

5. Divisional Considerations

Silver Spring

- Collocate the Headquarters Division of ARL with NCEP.
- Strengthen the Silver Spring Transport and Dispersion activity, so as to provide the necessary services to NCEP and the NWS in general.

Research Triangle Park

- Work to increase NOAA support of ASMD to a level in the range 30% to 40% of the EPA level.
- Complete interagency arrangements to permit staffing with contractual employees.

Oak Ridge

- Formalize Climate Reference Network arrangements with NESDIS
- Obtain NOAA support for the CO_2 sequestration network (under Ameriflux)
- Formalize the ETOS series of studies within the NOAA air quality program
- Complete light aircraft lease and/or acquisition actions
- Continue association with other agencies on urban dispersion and related issues

Idaho Falls

- Complete a next generation atmospheric tracer capability
- Field-test super-balloon technologies

Boulder

- Ensure long-term base support for SURFRAD
- Ensure funding for the Central UV Calibration Facility, and institutionalize its WMO/GAW role

Las Vegas

- Construct a long-term agreement with DOE/NNSA regarding meteorological and atmospheric dispersion support, and associated research, related to national defense programs.
- Rationalize collaborative research activities with DRI via CIASTA.
- Integrate data from the IMPROVE network with AIRMoN.